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REFLECTING MIRROR HAVING VARIABLE SPECTRAL REFLECTION CHARACTERISTIC
[Kahenbunkou hanshatokusei wo yuusuru hanshakyou]

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SPECIFICATION

/101*

1. Title of the Invention

Reflecting Mirror Having Variable Spectral Reflection Characteristic

2. Claims

(1) A reflecting mirror having a variable spectral reflection characteristic, characterized by having a structure in which an electrooptic optical control element capable of having its transmission rate changed electrically is disposed between multiple reflecting optical elements having different spectral reflection/transmission characteristics and in which the spectral reflection characteristic is changed by the transmission rate of the electrooptic transducer being altered.

(2) A reflecting mirror according to Claim 1, characterized by having a structure in which at least one of the multiple reflecting optical elements is composed of a multilayer-film interference filter and in which the electrooptic optical control element is composed of an electrochromic material.

3. Detailed Description of the Invention

The invention relates to a reflecting mirror capable of changing spectral reflection characteristic, specifically to reflecting mirrors capable of electrically changing the spectral reflection characteristic.

In general, the taking lenses of cameras and the like and the object lenses of microscopes and the like are well compensated for visible rays but have not been compensated for infrared light, and light fluxes that

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* Numbers in the margin indicate pagination in the foreign text.

passed through an imaging lens L form focal points at different locations on the optical axis depending on the wavelengths as shown in Fig. 1A. Assuming that the gaps between the focal point of a reference wavelength and the focal points of the rays of different wavelengths are ΔZmm, the chromatic aberration characteristic illustrated in Fig. 1B is observed. In other words, the best image plane f corresponding to a reference beam that represents visible lights and the best image plane f′ corresponding to a wavelength of infrared light will have a gap of ΔZ. Moreover, light rays from general optical sources that light up an object, test sample, etc. have various spectral characteristics as shown in Fig. 2A. In Fig. 2A, the curve A indicates the spectral characteristics of fluorescent light, the curve B indicates the spectral characteristics of daylight, and the curve C indicates the spectral characteristics of a tungsten lamp.

Incidentally, the spectral sensitivity distribution of a photoelectric transducer, which is utilized for focal point detection while built inside a focal point detector, varies somewhat depending on whether it is a PN silicon photodiode (SPD) or a charge coupled device (CCD) of a PN connection, but it has a wide range of sensitivity that includes not only the visible ray regions but also the infrared /102
regions. Therefore, if, for example, the object is illuminated by a fluorescent lamp having the spectral distribution, such as that shown by curve A of Fig. 2A, the focal point will be detected mostly by means of visible rays (400nm - 700nm), and the focal point detector therefore indicates the correct focal point (f in Fig. 1A). However, if the object is illuminated by light such as the daylight of curve B or that of a tungsten

lamp of curve C in Fig. 2A, the focal point indicated by the focal point detector shifts to, for example, the right-hand side of Fig. 1A, which is the direction of the best image plane f′ of infrared light, depending on the degree at which infrared light is contained in the light flux used for focal detection. In this manner, a conventional device has a disadvantage in that the detected location of the focal point becomes shifted toward the infrared side depending on the type of the illumination source.

The above problem can be solved by inserting a filter that transmits only light of the visible range into the optical path that reaches the photoelectric transducer. However, strictly limiting the range of the detected wavelength to the visible range is effective for removing the influences of infrared aberration but has a disadvantage in that it substantially increases the lower brightness limit of the object or test sample for which the focal point can be detected. Moreover, installing a visible-range-only filter around the inner peripheries of the optical path will eliminate the possibility of measuring distances by using infrared light based on the spectral sensitivity of an infrared film or the possibility of actively measuring distances by irradiating infrared light.

The aim of the present invention is to solve the above shortcomings and to provide a reflecting mirror with a variable spectral reflection characteristic capable of electrically changing the spectral characteristic of a light flux directed toward the photoelectric transducer for focal point detection based on the spectral characteristic

of the illuminated light.

In order to achieve the above aim, the invention is characterized in that an electrooptic optical control element capable of having its transmission rate changed electrically is disposed between multiple reflective optical elements having different spectral reflection/transmission characteristics and in that the spectral reflection characteristic of the reflecting mirror is changed by altering the transmission rate of the electrooptic optical control element.

In the following, the invention will be explained in detail based on embodiments illustrated in the accompanying drawings.

Figure 3 is a magnified cross-sectional drawing showing the structure of a first embodiment of the invention, and Fig. 3A is a graph showing the spectral reflection characteristic of the first embodiment.

As shown in Fig. 3, the reflecting mirror of the first embodiment has a structure in which a metal film layer 1 having a high reflection factor such as aluminum (A*l*) or silver (Ag) is disposed on a substrate G, such as flat glass, in which an electrooptic optical control element layer (hereafter, simply "EC layer") 2, such as an electrochromic element, capable of having its transmission rate changed electrically is disposed on the metal film layer, and in which a multilayer-film interference filter layer 3 is disposed on the electrooptic optical control element layer. As indicated by the solid line I in Fig. 3A, the metal film layer 1 has a high reflection factor for light of a relatively wide wavelength range. Moreover, the multilayer-film interference filter layer 3 is structured so that it mostly reflects the light of the visible range and transmit

the light of the infrared range as indicated by, for example, the chain line II in Fig. 3A.

Since the reflecting mirror of the first embodiment shown in Fig. 3 has the above structure, it reflects both visible light and infrared light when the EC layer 2 is electrically controlled to transmit light. In other words, visible light is reflected by the multilayer-film interference filter layer 3, and the remaining infrared light that passed through the multilayer-film interference filter layer 3 is reflected by the metal film layer 1 after being transmitted through the EC layer 2, and then moves forward while being transmitted through the EC layer 2 and multilayer-film interference filter layer 3 again. Moreover, when the EC layer 2 changes into a non-transmitting state, the infrared light that passed through the multilayer-film interference filter layer 3 becomes absorbed by the EC layer 2. As a result, only the visible light will be reflected by the reflecting mirror.

For this reason, by detecting the focal point by using a light flux reflected by the reflecting mirror of the first embodiment in a focal point detector in which a focal point is detected by using an electrooptic transducer, such as a SFD or CCD, having a wide range of sensitivity that includes the infrared region, even a bright object can have its distance measured with high accuracy by means of only visible light by not allowing the EC layer 2 to transmit light. Also, if the object is dark, its distance can be measured, although the accuracy may be somewhat inferior, by allowing the EC layer 2 to transmit light in order to cause the infrared light to be reflected and by thus using the reflected light. Moreover,

if using a distance measuring means by means of infrared light /103 irradiation in combination, the EC layer 2 should be made to transmit light in order to cause the infrared light to be reflected, or the EC layer should normally be kept in a non-transmitting state so that only visible light will be reflected. On the other hand, since the focal point detection accuracy is required only near the focal point, it is possible to perform distance measurement by using light containing infrared light in the areas other than the areas near the focal point and to keep the EC layer 2 in the transmitting state in order to increase the response output of the detecting system, and it is also possible to control the EC layer 2 to be in the non-transmitting state and to strictly use only visible light in the areas near the focal point in order to increase the distance measuring accuracy.

Figure 4 is a magnified cross-sectional drawing showing the structure of a second embodiment of the invention, and Fig. 4A is a graph showing the spectral reflection characteristic of the second embodiment.

In the second embodiment shown in Fig. 4, a second multilayer-film interference filter layer 4 is disposed between a substrate G and an EC layer 2, and a first multilayer-film interference filter layer 3 is disposed on the EC layer 2. As indicated by the chain line II of Fig. 4A, the first multilayer-film interference filter layer 3 has a similar spectral reflection characteristic as that of the multilayer-film interference filter layer 3 of the first embodiment shown in Fig. 3, and the second multilayer-film interference filter layer 4 is structured in a manner, such that, as indicated by the solid line III of Fig. 4A, the

cutoff wavelength extends toward the infrared side beyond the first multilayer-film interference filter layer 3 and such that it reflects light of the near-infrared region. Therefore, the reflecting mirror of the second embodiment functions as a visible-range reflecting mirror in the same manner as in the first embodiment when the EC layer 2 is in the non-transmitting state and functions as a visible-range and near-infrared-range reflecting mirror when the EC layer 2 is in the transmitting state.

Figure 5 is a magnified cross-sectional drawing showing the structure of the third embodiment having the same functions as those of the second embodiment shown in Fig. 4. In Fig. 5, a metal film layer 1 of, for example, Al or Ag, that is similar to that of the first embodiment (Fig. 3) is vapor deposited on a substrate G, and an infrared absorbing layer 5 is disposed between the metal film layer 1 and EC layer 2. From among the rays made incident on the infrared absorbing layer 5, the rays of the infrared-range wavelengths become absorbed by the absorbing layer 5, while the remaining rays of the visible-range to near-infrared-range wavelengths become reflected by the metal film layer 1. The spectral reflection characteristic of light reflected via the infrared absorbing layer 5 and metal film layer 1 can be made the spectral reflection characteristic indicated by the solid line II in Fig. 4A, which is similar to the spectral reflection characteristic of the second multilayer-film interference filter layer 4 shown in Fig. 4. Moreover, a multilayer-film interference filter layer 3 that is the same as the first multilayer-film interference filter layer of the second embodiment is disposed on the EC layer 2, and

the spectral reflection characteristic of this layer 3 can also be indicated by the chain line II shown in Fig. 4A. Therefore, the reflecting mirror of this third embodiment also functions as a visible-range reflecting mirror when the EC layer 2 is in the non-transmitting state and functions as a visible-range to near-infrared-range reflecting mirror when the EC layer is in the transmitting state.

Incidentally, a normal film demonstrates spectral sensitivity that covers roughly the entire visible range as indicated by chain line D in the spectral sensitivity graph shown in Fig. 8, and an infrared film demonstrates spectral sensitivity such as that indicated by solid line E with point λ (=750nm) as the center. For this reason, focal point detection should be performed by means of only infrared light in which λ (=750nm) is the center by, when using a normal film, using the second embodiment shown in Fig. 4 or the third embodiment shown in Fig. 5 and providing the reflecting mirror with a spectral reflection characteristic such as that of chain line II of Fig. 4A and, when using an infrared film, by switching the spectral reflection characteristic to solid line III (which is the same as solid line III of Fig. 9) and installing a filter having a transmittance characteristic such as that indicated by dotted line V of Fig. 9 in front of the taking lens or in an appropriate location.

Figure 6 is a magnified cross-sectional drawing showing the structure of the fourth embodiment of the invention, and Fig. 6A is a graph showing the spectral reflection characteristic of the fourth embodiment.

In Fig. 6, a substrate G, a metal film 1, a first EC layer 2, and a first multilayer-film interference filter layer 3 have exactly the same

structures as those of the substrate, metal film, EC layer, and multilayer-film interference filter layer, respectively, of the first embodiment (Fig. 3). Moreover, solid line I and chain line II shown in Fig. 6A indicate the spectral reflection characteristics of the metal film layer 1 and first multilayer-film interference filter layer 2, respectively, of Fig. 6 and are exactly the same as solid line I and chain line II of Fig. 3A.

A second EC layer 2′ is further provided on the first multilayer-film interference filter layer 2, and a third multilayer-film interference filter layer 6 is provided on the second EC layer 2′. As indicated by dotted line IV in Fig. 6A, this third multilayer-film interference filter layer 6 is structured in a manner such that its spectral reflection characteristic reflects a portion of visible light that has relatively short wavelengths and transmits the remaining visible-range and /104
near-infrared-range light.

Therefore, the fourth embodiment of Fig. 6 has equivalent functions as those of the first embodiment when the second EC layer 2′ is in the transmitting state. In other words, if the first EC layer 2 is in the non-transmitting state, the third multilayer-film interference filter 6 reflects light of wavelengths up to about 550nm as indicated by dotted line IV in Fig. 6A, and the first multilayer-film interference filter layer 3 reflects the remaining visible light. The near-infrared light and infrared light that passed through the first multilayer-film interference filter layer 3 become absorbed by the first EC layer. Therefore, only visible light will be reflected in this case. If the first

EC layer 2 is in the transmitting state, all of the light that passed through the first multilayer-film interference filter becomes reflected by the metal film layer 1. On the other hand, if the second EC layer 2′ is shifted to the non-transmitting state, only light having the wavelengths of part of the wavelength range of visible light becomes reflected, while all of the remaining light becomes absorbed by the second EC layer 2′. In other words, according to the fourth embodiment, the range of the reflected wavelengths can be switched among three patterns by controlling the two EC layers, 2 and 2′. Needless to say, the range of the reflected wavelengths can be divided further by increasing the number of the interference filters having different spectral reflection characteristics and the number of the EC layers.

By using the reflecting mirror of the fourth embodiment, even a pattern containing red and blue of the same density that cannot be identified even when all of the visible light is utilized can be detected by controlling the second EC layer 2′ to be in the non-transmitting state and by thus switching its spectral reflection characteristic to that of dotted line IV of Fig. 6A.

Figure 7 is a magnified cross-sectional drawing showing the structure of a fifth embodiment of the invention in which the infrared aberration of the lens is corrected. In order to correct the infrared aberration, ΔZ, of the lens indicated in Fig. 1A, a spacer 7, such as a glass layer, having a predetermined thickness is disposed between the EC layer 2 and multilayer-film interference filter layer 3 disposed on the substrate G and metal film layer 1 having the same structures as those of the first

embodiment shown in Fig. 3.

In a case in which light is perpendicularly made incident and reflected on the reflecting mirror, the thickness of the spacer 7 can be set so that the following equation will be satisfied in order to make it possible to perform aberration correction by canceling out the infrared aberration of the incident light and reflected light.

$$t = \frac{n \cdot \triangle Z}{2}$$

(wherein the predetermined thickness, reflectance, and infrared aberration of the spacer 7 are t, n, and $\triangle Z$, respectively.) In other words, since detecting a focal point by means of infrared light is equivalent to lowering the position of the focal point detection plane on the optical axis by $\triangle Z$, the focal point detector of, for example, a camera can obtain pictures in which the visible-light focuses coincide with the film surfaces at all times. In Fig. 7, correction of infrared aberrations is made possible by providing the reflecting mirror of the first embodiment with a spacer, and the embodiments of Fig. 4 through Fig. 6 should also be provided with spacers of thicknesses that correspond to the degrees of aberration in the same manner. Moreover, if the lens can be replaced, and the infrared aberration varies depending on the lens, the thickness t of the spacer should be set in accordance with the average value of the different infrared aberrations.

In each of the embodiments illustrated in Fig. 3 through Fig. 7, a front-surface reflecting mirror having a variable spectral reflection

characteristic is formed on the surface of the substrate G, such as flat glass, by layering various films, but it can be provided as a rear-surface reflecting mirror 1 instead. Needless to say, when providing it as a rear-surface reflecting mirror, the order of arrangement will be reversed as in, in the case of Figure 3 for example, the multilayer-film interference filter layer 3 being in contact with the transparent substrate G and the metal film layer 1 being on the air side. In this case, in order to prevent the occurrence of a ghost, the substrate G should be replaced by a square prism P, and the inclined surface of this square prism P should be provided with the multilayer-film interference filter layer 3, EC layer 2, and metal film layer 1 in that order.

Moreover, in a case in which light of the near-infrared range is reflected while light of the infrared range having wavelengths longer than those of the near-infrared range is transmitted (see solid line III of Fig. 4A) as in the case of the second multilayer-film interference filter layer 4 of the second embodiment shown in Fig. 4, the film layers should be sandwiched by two square prisms, P_1 and P_2, and the first multilayer-film interference filter layer 3, EC layer 2, and second multilayer-film interference filter 2 should be provided in that order from the side of the prism P_1 on which light is made incident as illustrated in the sixth embodiment shown in Figure 11. In this case, it is permissible to form all of the film layers on the inclined prism surface of /105 either one of the prism P_1 or prism P_2 and to then paste them together, or to form the film layers on the inclined surfaces of both prisms, P_1 and P_2, and to then join them together. For example, in the sixth embodiment

shown in Fig. 11, the prism P_1 is provided with a first multilayer-film interference filter layer 3 that reflects visible light and transmits infrared light, and an EC layer 2 is provided thereon. Also, the prism P_2 is provided with a second multilayer-film interference filter layer 4 that reflects light of the near-infrared range as indicated by solid line III of Fig. 4A and that transmits the remaining light, and the two prisms, P_1 and P_2, should then be pasted together. By disposing a spacer 7′ between the EC layer 2 and second multilayer-film interference filter layer 4 as shown in Fig. 12 at the time of the above pasting, and by setting the thickness of the spacer 7′ to be roughly a predetermined one as in the case of the spacer 7 of the fifth embodiment shown in Fig. 7, aberration correction of near-infrared light can be performed.

Figures 13 and 14 are the drawings of layouts in which a reflecting mirror of the invention is provided in the detection optical path of the focal point detector of a single lens reflex camera. In Fig. 13, an electrooptic transducer W is positioned at the bottom part of the camera, and part of the light from the object that passed through the taking lens L becomes directed toward the light-receiving surface of the electrooptic transducer W, which is conjugated to the film surface, by the reflecting mirror Mv of the invention after passing through a movable mirror M. Since the reflecting mirror Mv moves together with the movable mirror during the instance of shooting as commonly known, it should be composed of a plane mirror such as those shown in Fig. 3 through Fig. 7. Moreover, Fig. 14 is an example in which the electrooptic transducer W is positioned inside the finder of a camera. In this case, a reflecting mirror Mv′ of

an embodiment of the invention is placed inside a focal-point detection optical path, which is directed toward the electrooptic transducer W from the finder's optical path reflected by the movable mirror M. Since this reflecting mirror Mv' does not move, it is desirable that the substrate be a prism as illustrated in Fig. 10 through Fig. 12. Needless to say, in any focal-point detection optical device, a reflecting surface of the invention can be applied to the reflecting surface inside the optical path in accordance with its optical system.

In the above-described manner, the invention is structured in a manner such that the spectral characteristic can be changed to a predetermined one by the spectral reflection characteristic of the reflecting mirror (or prism) being electrically controlled. Therefore, it can be placed in the focal-point detection optical path of the focal point detector to increase the detection accuracy. Moreover, since the spectral reflection characteristic is electrically switched, the switching structure is simple, and the invention can therefore be applied to various types of illumination sources.

4. Brief Description of the Drawings

Figure 1A is a drawing for explaining the infrared aberration of a taking lens, and Figure 1B is a chromatic aberration characteristic graph of the taking lens. Figure 2A is a spectral distribution characteristic graph of various types of optical sources, and Figure 2B is a spectral sensitivity graph of an electrooptic transducer. Figure 3 is a structural drawing of the first embodiment of the invention, and Figure 3A is a spectral reflection characteristic graph of the first

embodiment. Figure 4 is a structural drawing of the second embodiment of the invention, and Figure 4A is a spectral reflection characteristic graph of the second embodiment. Figure 5 is a structural drawing of the third embodiment of the invention. Figure 6 is a structural drawing of the fourth embodiment of the invention, and Figure 6A is a spectral reflection characteristic graph of the fourth embodiment. Figure 7 is a structural drawing of the fifth embodiment of the invention. Figure 8 is a film sensitivity distribution graph of a normal film and an infrared film. Figure 9 is an explanatory drawing indicating the spectral reflection characteristic of the visible light range of the embodiment of Fig. 4 or Fig. 5 along with the spectral transmission characteristic of an infrared filter. Figure 10 is a structural drawing of the sixth embodiment of the invention in which the rear surface of the prism is provided with the reflecting layer. Figures 11 and 12 are structural drawings of the seventh embodiment and eighth embodiment, respectively, of the invention in which a reflecting layer is sandwiched between two prisms. Figures 13 and 14 are the layout drawings of different embodiments in which a reflecting mirror of the invention is installed inside the detection optical path of the focal point detector of a single lens reflex camera.

1, 3, 4, 6 = reflecting optical element

2, 2′ = electrooptic transducer

5 = infrared absorbing layer

7 = spacer

G = substrate

P, P_1, P_2 = prism

Figure 1A

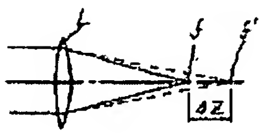


Figure 1B

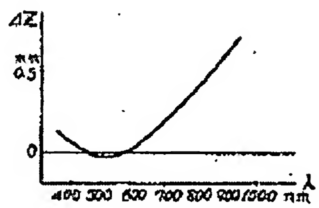


Figure 2A

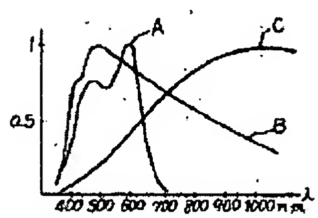
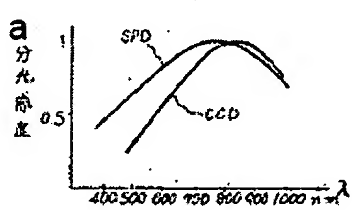


Figure 2B



Key: a) spectral sensitivity.

Figure 3

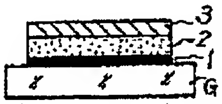
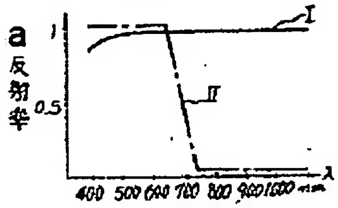


Figure 3A



Key: a) reflection factor.

Figure 4

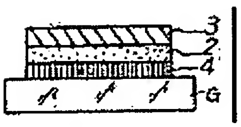
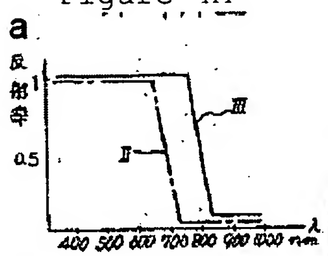


Figure 4A



Key: a) reflection factor.

Figure 5

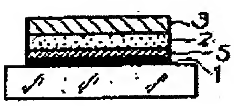


Figure 6

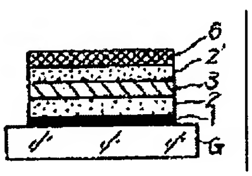
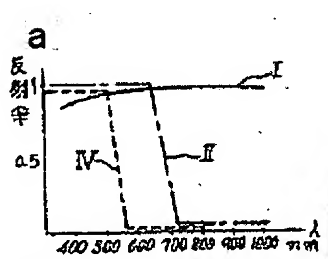


Figure 6A



Key: a) reflection factor.

Figure 7

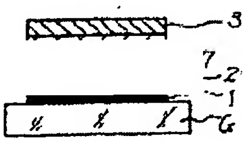
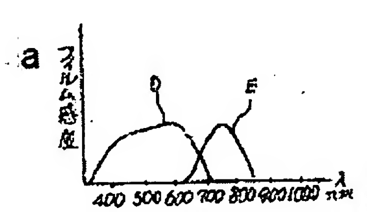


Figure 8



Key: a) film sensitivity.

Figure 9

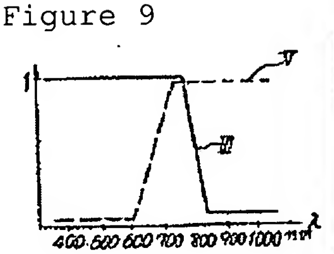


Figure 10

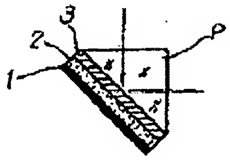


Figure 11

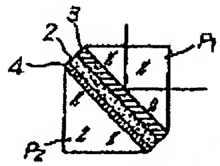


Figure 12

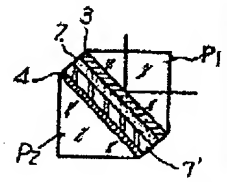


Figure 13

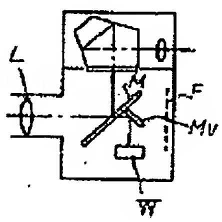


Figure 14